CHAPTER 7

The Potential Economic Ramifications of Offshore Aquaculture

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This chapter provides a broad overview of the economic feasibility and potential contributions to the U.S. economy of offshore aquaculture.

Introduction

Development and promotion of offshore aquaculture has been proposed as one approach for satisfying an increasing domestic demand for seafood and promoting community maintenance and development. In particular, considering the stable status of wild harvests, as regulatory strategies become increasingly restrictive and thus reduce the domestic, wild caught seafood supply, it will become increasingly difficult to satisfy rising domestic demand due to both population growth and more healthy food claims, even with expanding imports. In 2005, the U.S. total supply of edible fishery products equaled 11.8 billion pounds; domestic landings of edible product equaled 8 billion pounds; imports equaled 10.2 billion pounds; and exports equaled 6.4 billion pounds. Between 1995 and 2005, imports increased from 3.1 to 10.2 billion pounds, or by 7.1 billion pounds. Domestic landings decreased from 9.8 to 8 billion pounds during this same period. In contrast, during the same period between 1995 and 2005, production of domestic aquacultured products in the U.S. increased from 690.4 to 788.7 million pounds (NMFS, 1996, 1997 and 2007). There is, thus, substantial evidence to believe that aquaculture can succeed and help satisfy a growing domestic demand for seafood.

Successful development and promotion of offshore aquaculture, however, is not without substantial perils or problems. Potential problems exist, such as the accidental release of non-indigenous species (if such species are permitted), large-scale mortalities, lack of adequate infrastructure, immature technology, and inadequate economic incentives due to higher investment and production costs. These are all extremely important potential limitations, which will need to be addressed to successfully stimulate and develop offshore aquaculture, but there is an even more basic issue. Simply put: Is offshore aquaculture economically viable or feasible, and if so, what are the economic ramifications in terms of contributions to the U.S. economy?

This chapter provides a broad overview of the economic feasibility and potential contributions to the U.S. economy of offshore aquaculture. For the purpose of assessing economic feasibility, a series of bio-economic models (based on engineering type models and information) are initially developed. The bio-economic and engineering models and information, however, are also used to assess initial stocking densities, growth and survivability, time required to reach marketable size, and subsequently, net returns. Five species or broad aggregates are considered: (1) Atlantic cod, (2) salmon, (3) winter flounder, (4) blue mussel, and (5) sea scallops. They represent, thus, three species of finfish and two species of shellfish.

¹ Chapter 6 provides a comprehensive discussion of the economic feasibility analysis and the corresponding models and assumptions.

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For the finfish species, the finfish production technologies considered in this chapter involve large, offshore cage farms employing a high level of automation. Two different technologies are considered for mollusks: a longline system for grow-out is considered for the blue mussel, and a seabed seeding technology is considered for scallop grow-out. Subsequent to assessing economic feasibility, an input/output (I/O) model is used to determine the potential economic contributions of offshore aquaculture for the five selected species or products.² Economic impacts are expressed in terms of sales or output, income, and employment. All dollar values are expressed in terms of year 2005 constant dollar values. Impacts are assessed relative to direct, indirect, and induced impacts. Direct impacts reflect the economic impacts directly generated by the producing sector. Indirect effects reflect the economic impacts of economic activity supporting the producing sector (fuel dealers who sell the fuel necessary to power vessels used by aquaculture producers must also purchase fuel and other goods and services from other businesses, for example). Induced impacts reflect the economic activity generated by expenditures of wages and salaries received by individuals in all producing and support sectors (Kirkley et al., 2005).

The input/output model facilitates estimation and assessment of the economic contributions of the various aquaculture operations in terms of sales (or output), income, and employment generated. The I/O models developed for the assessment of the economic impacts consider the producers (for example, an aquaculture operation), wholesalers, grocery stores and fish markets, and restaurants—or, final consumer sector. In actuality, however, grocers and restaurants represent separate industries, and the associated economic impacts of these two sectors should really be attributed to these sectors independently. They could easily substitute other products for aquacultured products. They are, nevertheless included to illustrate the potential magnitude of how offshore aquaculture could contribute to the economy of the United States.

In this part, it is necessary to mention that shellfish aquaculture differs from finfish aquaculture because it does not need feed. Therefore, for shellfish aquaculture, indirect effects do not need to consider the feed industry, while for finfish aquaculture, they do. In addition, set-up and processing costs will differ. It might be helpful to compare some differences between them before making a detailed calculation.

The Economic Feasibility and Contributions of Shellfish Aquaculture

Initially provided are an assessment and potential impacts for the shellfish species, blue mussels and sea scallops. Mussels will be grown on ropes suspended vertically from longline harness sets. Each harvest consists of a 120-meter-long horizontal longline held in place about seven meters below the surface by submerged flotation spheres and anchored to the bottom. Approximately 200 culture ropes are suspended from each longline to a depth of five meters above the seafloor. At full-scale operation, which is projected to be realized in three years, an offshore aquaculture plant will operate 120 longlines. Scallops will be grown using a seabed seeding technology. Scallops are to be seeded over a 143-acre site. The mussel operation is assessed over a 10-year period, and the scallop operation is assessed over a 20-year period.

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 $^{^2}$ A description of the I/O model is presented in chapter 13, Kirkley et al. (2005), "A Users Guide to the U.S. National Offshore Aquaculture Model for Assessing Economic Impacts.

Blue Mussel (Mytilus edulis)

The growth of blue mussels, as well as the growth of scallops and finfish, is estimated based on a discrete time version of the Beverton-Holt (1957) model, which relates growth to number of animals and weight of animals. The time period considered for the economic feasibility of producing blue mussels via offshore aquaculture was determined by the useful life of longlines, which is ten years. The bio-economic assessment considers longline installation, spat collection, socking operation, maintenance, and harvesting. The assessment also includes purchase of a used vessel, which will be employed during the first three years, and then the purchase of a new vessel in the fourth year of the operation, which is the approximate time required to bring the operation up to full scale. All production activities are assumed to be equivalent to constant returns to scale; that is, a constant proportionate increase in all factors of production generates the same proportionate increase in outputs, or the production of mussels.³

The up front investment cost for a mussel operation is approximately \$1.1 million. This includes the purchase and installation of longlines, a used vessel, and other items essential to production. Additional costs include expendable supplies, vessel and equipment maintenance, and support for shore-side activities (Table 7.1). The total constant dollar cost of the operation over the 10-year period equals \$4.62 million.⁴ Over the 10-year period, it is projected that the mussel operation will generate, after deducting costs, a net present value of approximately \$2.7 million (Table 7.2). The average annual harvest will be approximately 892 metric tons, or 1.97 million pounds per year. Average annual revenue will approximate \$1.2 million per year, with a product price of approximately \$0.60 per pound. The break-even price is \$0.35 per pound; that is, if prices received for scallops fall below \$0.35 per pound, it will not long be financially feasible to operate the mussel operation, based on assumptions above.

One problem with the initial feasibility analysis is the assumption of constant returns to scale. It is, thus, not feasible to assess the potential economic impacts of mussel operations if expanded. There is no information to indicate the potential number of mussel operations, and thus, our assessment of the potential economic contributions can only be made in terms of either gross sales for a single plant, or on a per-\$1-million-of-sales for mussel aquaculture basis.

Based on the national aquaculture input/output model, it is estimated that an annual gross revenue of \$1.2 million will generate a total of \$6.49 million in total sales or output, \$3.33 million in income, and 92 full- and part-time jobs for the U.S. economy (Table 7.3). These impacts represent the impacts over all sectors, from the aquaculture operation to retail sales. The largest impacts are generated in the restaurant and primary producer (aquaculture operation) sectors. Retail sales by grocers generate a total of \$3.5 million in total sales or output, \$2.03 million in income, and 62 full- and part-time jobs. The aquaculture-producing sector generates \$2.67 million in total sales, \$1.14 million in income, and 25 full- and part-time jobs.

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³ Constant returns to scale is assumed for the production of all species.

⁴ The constant dollar cost is based on a discount rate of 7 % per year and is necessary to adjust the dollar values for inflation and the opportunity cost of capital.

⁵ Economic impacts, except employment, are in terms of year 2005 constant dollar values. Employment is expressed in terms of the number of full- and part-time jobs.

Table 7.1. Basic production and cost requirements, blue mussels.

Table 7.1. Dasic production and co	st requirements, bro	ic illusseis.
Description	Unit	Value
longlines at full capacity	number/farm	120
longline installation cost ^a	\$/longline	10,000
expendable supplies ^b	\$/longline/year	1,700
used vessel acquisition	\$/vessel	70,000
used vessel maintenance	\$/vessel/year	10,000
used vessel upgrade & equipment c	\$/vessel	25,000
equipment maintenance	\$/year	5,000
used vessel variable and crew cost	\$/day	1,500
new custom vessel construction	\$	800,000
new custom vessel maintenance	\$/year	30,000
new vessel variable and crew cost	\$/day	1,000
on shore cost d	\$/year	173,000
annual discount rate		0.07

Notes:

- a. Including 2 anchors (\$2,000), 2 corner buoys (\$2,000), rope and chain (\$2,000), flotation (\$2,000), and assembly and deployment (\$2,000)
- b. Including spat collectors, grow out ropes, socking material, bag, etc.
- c. Including stripper/declumper/grader and continuous socking machine
- d. Including CEO/captain salary (\$100,000/year) and vessel dockage, etc. (\$20,000)

Table 7.2. Estimated net present value, investment, harvest, and cost, blue mussels.

Description	Unit	Value
net present value	\$ million	2.659
Investment ^a	\$ million	1.114
average fish harvest ^b	metric ton/year	892
total cost	\$ million	4.624
Cost Share		
longline installation	%	24.1
expendable supplies	%	15.5
vessel acquisition & maintenance	%	19.5
vessel variable cost (fuel, crew, etc.)	%	13.4
onshore and other	%	27.5
total	%	100

Notes:

b. At full capacity annual output is 1,200 metric tons

a. Longline system only

Table 7.3. Economic contributions of single blue mussel operation, \$1.2 million in sales.

Table 7.5. Economic contributions of single blue i	nussei of	ici audii,	φ1. 4 IIIII	non m sa	
Impacts of Aquaculture Blue Mussels Offshore Shipments – Producers					
	Direct	Indirect	Induced	Total	
	Impacts	Impacts	Impacts	Impacts	
Labor Income Impacts (millions of dollars)	0.50	0.18	0.45	1.14	
Output Impacts (millions of dollars)	0.73	0.58	1.36	2.67	
Employment Impacts (full-time and part-time jobs)	9.87	3.75	11.86	25.48	
Impacts of Aquaculture Blue Mussels Offshore Sh	ipments	– Whole	salers		
	Direct	Indirect	Induced	Total	
	Impacts	Impacts	Impacts	Impacts	
Labor Income Impacts (millions of dollars)	0.03	0.01	0.02	0.06	
Output Impacts (millions of dollars)	0.03	0.02	0.07	0.12	
Employment Impacts (full-time and part-time jobs)	0.54	0.11	0.60	1.25	
Impacts of Aquaculture Blue Mussels Offshore Shipments – Grocers					
	Direct	Indirect	Induced	Total	
	Impacts	Impacts	Impacts	Impacts	
Labor Income Impacts (millions of dollars)	0.06	0.01	0.05	0.11	
Output Impacts (millions of dollars)	0.04	0.01	0.15	0.20	
Employment Impacts (full-time and part-time jobs)	2.12	0.11	1.26	3.49	
Impacts of Aquaculture Blue Mussels Offshore Sh	ipments	– Restau	rants	_	
	Direct	Indirect	Induced	Total	
	Impacts	Impacts	Impacts	Impacts	
Labor Income Impacts (millions of dollars)	1.06	0.10	0.87	2.03	
Output Impacts (millions of dollars)	0.60	0.28	2.63	3.50	
Employment Impacts (full-time and part-time jobs)	37.04	2.24	22.76	62.04	
Impacts of Aquaculture Blue Mussels Offshore Sh	ipments	– All Sec	ctors	_	
	Direct	Indirect	Induced	Total	
	Impacts	Impacts	Impacts	Impacts	
Labor Income Impacts (millions of dollars)	1.64	0.30	1.40	3.33	
Output Impacts (millions of dollars)	1.40	0.89	4.21	6.49	
Employment Impacts (full-time and part-time jobs)	49.57	6.22	36.48	92.27	

Sea Scallops (Placopecten magellanicus)

The economic feasibility of using aquaculture to produce sea scallops is based on a 20-year life cycle. A 20-year cycle permits ten, two-year cycles of harvesting and marketing scallops. The farming operation is scaled to produce 100,000 pounds of scallop meat every two years. Baseline production assumptions include the following: 1) the farming site is two hours by boat from port; 2) the site is surrounded by markers with annual maintenance requirements of three hours of boat time; 3) the juvenile scallop collecting/depositing time per cycle is 142 days; 4) the farm area seeded is 143 acres; 5) scallops are sold at dockside for \$7 per pound of meat; 6)

the work day is 12 hours; and, 7) vessels are capable of capturing and bringing to the farming site an average of 40,000 juvenile scallops in one day.

Although a two-year production cycle is assumed, the equivalent annual production is 22.7 metric tons, or 50 thousand pounds per year. At \$7 per pound, the plant or production facility is projected to gross \$350.3 thousand per year. The input requirements (such as the number of buoys and moorings per farm, seeding density, etc.) are summarized in Table 7.4. The up front investment is \$52.7 thousand (Table 7.5). The expected net present value, or net return over the 20-year cycle, equals \$1.72 million. The total cost for one scallop operation over the 20-year period is \$2.11 million.

The annual economic contributions of the single scallop production facility equal \$1.98 million in sales or output, \$1.15 million in income, and 31 full- and part-time jobs. The production facility, itself, generates sales or output of \$730 thousand, \$430 thousand in income, and approximately 9 full- and part-time jobs. The largest contributions are generated by the restaurant sector—\$1.14 million in sales or output, \$670 thousand in income, and 21 full- and part-time jobs. Expanding the number of production facilities simply scales the magnitude of the impacts (for example, two plants would be expected to generate \$3.96 million in sales, \$2.3 million in income, and 62 full- and part-time jobs).

Table 7.4. Basic production and cost requirements, sea scallop.

Description	Unit	Value
marker buoys & moorings	number/farm	14
unit cost	\$/mooring set	3,000
annual mooring maintenance	\$/mooring set/year	150
total vessel cost	\$/day	2,000
seeding density	1,000 scallops/acre	40
mortality/loss rate to harvest	%	50
average size at harvest	lbs (meat)	0.035
onshore cost *	\$/year	20,000
annual discount rate		0.07

Note: * Management and administration.

Table 7.5. Estimated net present value, investment, harvest, and cost, sea scallop.

Description	Unit	Value
Cost		
net present value	\$ million	1.723
investment ^a	\$	52,675
average scallop harvest b	metric ton/year	22.7
Total cost	\$ million	2.110
Cost Share		
marker buoys & moorings	%	2.5%
annual mooring maintenance c	%	1.0%
mooring maintenance d	%	5.4%
collecting/depositing cost ^d	%	78.9%
harvest cost ^d	%	1.6%
onshore cost	%	10.7%
Total	%	100%

- a. Marker buoys and moorings
- b. Scallops are harvested every other year
- c. Fix maintenance cost per year
- d. Cost associated with vessel usage

The Economic Feasibility and Contributions of Finfish Aquaculture

Estimation and assessment of the economic feasibility and potential economic contributions of finfish aquaculture is considerably more complicated. A Beverton-Holt model is used to project growth, numbers (abundance), and weight (biomass) of fish. In addition, various feed conversion ratios were used to help estimate the cost of feed for various finfish species. Revenues were estimated using price times quantity on a monthly basis, and subsequently aggregated to an annual basis. Costs and required investment levels were obtained from a wide variety of sources, which are detailed in Chapter 6 of this report. Details of the various bio-economic models used to conduct the assessments are also presented in Chapter 6.

The economic feasibility and contributions of using aquaculture to produce the three species of finfish are examined in this report. The production technologies for all three finfish species involve large offshore cage farms utilizing high levels of automation. In addition, production of all three species relies upon purchasing fingerlings and subsequently stocking and growing them to marketable size. Except for salmon, the purchase of fingerlings accounts for the largest cost share—41.8 % of the total cost of producing cod, and 55.1% of the total cost of producing winter flounder. The purchase of salmon fingerlings accounts for 18.8 % of the total cost of producing salmon.

Table 7.6. Economic contributions of sea scallop operation, \$350,300 in sales.

				i	
Impacts of Aquaculture Sea Scallops Offshore Shipments – Producers					
	Direct	Indirect	Induced	Total	
	Impacts	Impacts	Impacts	Impacts	
Labor Income Impacts (millions of dollars)	0.22	0.02	0.19	0.43	
Output Impacts (millions of dollars)	0.09	0.07	0.57	0.73	
Employment Impacts (full-time and part-time jobs)	3.51	0.41	4.95	8.87	
Impacts of Aquaculture Sea Scallops Offshore Sl	nipments	Whole	salers		
	Direct	Indirect	Induced	Total	
	Impacts	Impacts	Impacts	Impacts	
Labor Income Impacts (millions of dollars)	0.01	0.00	0.01	0.02	
Output Impacts (millions of dollars)	0.02	0.00	0.02	0.05	
Employment Impacts (full-time and part-time jobs)	0.16	0.03	0.17	0.36	
Impacts of Aquaculture Sea Scallops Offshore Sl	nipments	Groce	rs		
	Direct	Indirect	Induced	Total	
	Impacts	Impacts	Impacts	Impacts	
Labor Income Impacts (millions of dollars)	0.02	0.00	0.01	0.03	
Output Impacts (millions of dollars)	0.01	0.00	0.04	0.06	
Employment Impacts (full-time and part-time jobs)	0.62	0.03	0.37	1.03	
Impacts of Aquaculture Sea Scallops Offshore Sl	nipments	Restau	ırants		
	Direct	Indirect	Induced	Total	
	Impacts	Impacts	Impacts	Impacts	
Labor Income Impacts (millions of dollars)	0.35	0.03	0.29	0.67	
Output Impacts (millions of dollars)	0.18	0.08	0.88	1.14	
Employment Impacts (full-time and part-time jobs)	12.57	0.65	7.62	20.85	
Impacts of Aquaculture Sea Scallops Offshore Sl	nipments	– All Sec	ctors	_	
	Direct	Indirect	Induced	Total	
			Impacts	Impacts	
Labor Income Impacts (millions of dollars)	0.60	0.05	0.50	1.15	
Output Impacts (millions of dollars)	0.30	0.16	1.51	1.98	
Employment Impacts (full-time and part-time jobs)	16.86	1.13	13.12	31.11	

Atlantic Cod (Gadus morhua)

Cod aquaculture assumes that stocking and harvesting will be done on a year-round basis. Although the actual economic assessment is based on monthly activity, the average annual price equaled \$2.92 per pound. A 15-year period is used as the baseline assessment period. The baseline fixed cost per year is \$100 thousand. Operating costs are \$1,500 per day for fuel and other consumables, and personnel costs for a crew of four represent another \$1,500 per day. Annual production cost equals \$2.09/pound per year. Input requirements and associated costs involve purchasing cages, buying and installing moorings, acquiring fingerlings, supporting best management practices, and acquiring additional fixed and variable inputs (Table 7.7).

The up front investment cost ranges between \$2 and \$3.1 million (Table 7.8). The total cost of the project is between \$35.9 and \$59.9 million over the 15-year period. The variation is due to the possible production of baseline and high-end valued products. Expected production equals 177 metric tons, or 390.2 thousand pounds per month for a total of 4.7 million pounds per year. Gross revenue for the year is projected to equal \$13.7 million per year. The net present value over the 15-year period equals \$10.6 million for the baseline product, but appears to be negative (-\$13.4 million) for the high-end product. If the price falls below \$0.91 per pound, the baseline farm is no longer economically viable.

Revenues of \$13.7 million received by the farm generate total sales for the producing sector of \$38.8 million (Table 7.9). Of that total, the wholesale sector generates \$2.23 million in totals sales; the grocery sector generates \$2.96 million in total sales; and the restaurant sector generates \$32.2 million in total sales. Total output generated by all sectors equals \$76.3 million; total income equals \$33.7 million; and total employment generated across all sectors equals 1,013 full- and part-time jobs. The largest levels of impact occur in the restaurant and producing sectors. Total employment generated in the restaurant sector equals 571 full- and part-time jobs, and total employment generated in the producing sector equals 367 full- and part-time jobs.

Atlantic Salmon (Salmo salar)

Atlantic salmon is already successfully cultured in the northeast United States, and Maine has several producers. Cage culture is the primary method for culturing of salmon. Analysis of the economic feasibility of salmon culture is based on a 15-year cycle. The farm is assumed to produce salmon on a year-round basis. The expected harvest of salmon is 169 metric tons per month, or 4.5 million pounds per year. The assessment is based on a price of \$1.81 per pound. It is anticipated that the salmon farm will generate revenues of \$8.1 million per year. Both a baseline and a high-end product are considered in the assessment.

The total cost over the 15-year period is between \$31.3 (baseline product) and \$46.5 million (high-end product). Up front investment equals \$3.1 million. The input and cost requirements are summarized in Table 7.10; the economic performance and returns are summarized in Table 7.11. Overall, a salmon farm producing 4.5 million pounds per year is expected to yield a net return between \$29.5 million (baseline) and \$14.3 million (high-end). The analysis also indicates that if the price falls below \$0.91 per pound, the farm is not profitable.

Table 7.7. Basic production and cost requirements, Atlantic cod.

Parameter	Description	Unit	Baseline Value	High-end
				Value
V	cage volume per cohort	m ³	5,000	5,000
acq	cage purchase cost ^a	$$/m^3$	15.00	25
inst	cage mooring and installation cost	\$/m ³	3.00	3.00
ст	cage operating and maintenance cost b	\$/m ³ /year	1.00	6
stock	number of fingerlings stocked per cohort	1,000 fish	150	150
Sg	stocking weight	gram/fish	50	50
φ	ratio of water weight to fingerling weight during transport to farm		5	5
Sp	fingerling cost	\$/fish	0.85	1.50
Fp	feed cost	\$/kg	0.60	0.73
bfix	vessel fixed cost	\$/year	100,000	150,000
bvar	vessel variable and crew cost c	\$day	3,000	3,000
Ld	vessel payload	MT	30	30
trip	round trips per day		3	3
Sh	on shore cost d	\$/year	150,000	250,000
ins	insurance cost ^e	\$/year	50,000	300,000
fmv	feed management variable cost	\$/cohort/month	0	33.32
scf	solid control BMP plan fixed cost	\$/farm	0	1615.20
scv	solid control BMP plan variable cost	\$/month	0	21.15
dcf	drug and chemical control BMP plan fixed cost	\$/farm	0	1615.20
dcv	drug and chemical control BMP plan variable cost	\$/month	0	21.15
Aff	active feed monitoring fixed cost	\$/farm	0	10,000
afv	active feed monitoring fixed cost	\$/cohort/month	0	33.32
δ	annual discount rate		0.07	0.07

- a. Including feeder and other equipments
- b. Including fuel, utilities, diving, repair, etc.
- c. Including 4 crews (average \$25/hour)
- d. Including salaries for 1 manager and 2 office staff
- e. Insurance covers fish and other capital

Table 7.8. Estimated net present value, investment, harvest, and cost, Atlantic cod.

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Output	Description	Unit	Baseline	High-end
Variable			Value	Value
	net present value	\$ million	10.620	-13.375
NPV				
I	investment	\$ million	2.010	3.139
X(T)	average fish harvest	metric ton/month	177	177
N(T)	average number of fish	fish/month	120,535	120,535
	harvested			
W(T)	average harvest fish size	Kg	1.47	1.47
$12 \cdot E[fq(t)]$	average feed quantity	metric ton/year	2,765	2,765
Project Cost	total cost	\$ million	35.871	59.867
Cost Share	cage installation	%	5.6	5.2
	cage maintenance	%	2.8	10.2
	boat and crew	%	6.0	4.4
	fingerlings	%	39.5	41.8
	feed	%	40.9	29.8
	onshore and other	%	5.2	8.5
	total	%	100	100

The potential economic impacts of one offshore salmon farm are quite significant. The producing sector generates \$18.7 million in total sales or output, \$8.2 million in income, and approximately 189 full- and part-time jobs relative to producing sector activities (Table 7.12). Restaurant sales generate the second highest level of total output—at \$17.2 million. The sale of salmon by restaurants, however, generates the highest level of income—approximately \$10 million. The number of full- and part-time jobs generated by restaurant activity equals 304. Total sales (or output), income, and employment of all sectors equal, respectively: \$38.7 million, \$19.6 million, and 534 full- and part-time jobs.

Winter Flounder (Pseudopleuronectes americanus)

Winter flounder is a highly valued flounder by New England and mid-Atlantic consumers. Domestic landings of winter flounder, however, have substantially declined over time. In the 1970s and 1980s, annual landings were typically between 25 and 40 million pounds. Between 1994 and 2004, annual total landings have ranged between 8 and 13 million pounds. Given its highly desirable characteristics, winter flounder is an excellent candidate for offshore aquaculture.

The economic feasibility of producing winter flounder is based on a cage operation and a 15-year period. Expected production is 125 metric tons per month, or 3.3 million pounds per year. The feasibility analysis assumes an average annual price of \$4.60 per pound, which is considerably higher than previously observed ex-vessel prices for domestic wild product. The assessment is based on a monthly analysis and then aggregated up to an annual basis; then assessed relative to a 15-year production cycle.

Table 7.9. Economic contributions of cod operation, \$13.7 million in annual sales.

				1	
Impacts of Aquaculture Cod Offshore Shipments – Producers					
			Induced	Total	
	Impacts	Impacts	Impacts	Impacts	
Labor Income Impacts (millions of dollars)	4.00	3.71	4.54	12.25	
Output Impacts (millions of dollars)	11.69	13.50	13.64	38.83	
Employment Impacts (full-time and part-time jobs)	148.61	99.04	118.99	366.65	
Impacts of Aquaculture Cod Offshore Shipments – Wholesalers					
	Direct	Indirect	Induced	Total	
	Impacts	Impacts	Impacts	Impacts	
Labor Income Impacts (millions of dollars)	0.55	0.10	0.44	1.09	
Output Impacts (millions of dollars)	0.62	0.30	1.32	2.23	
Employment Impacts (full-time and part-time jobs)	10.30	2.18	11.45	23.93	
Impacts of Aquaculture Cod Offshore Shipments – Grocers					
	Direct	Indirect	Induced	Total	
	Impacts	Impacts	Impacts	Impacts	
Labor Income Impacts (millions of dollars)	0.90	0.08	0.72	1.70	
Output Impacts (millions of dollars)	0.56	0.22	2.18	2.96	
Employment Impacts (full-time and part-time jobs)	31.85	1.67	18.91	52.43	
Impacts of Aquaculture Cod Offshore Shipments	s – Restau	ırants			
	Direct	Indirect	Induced	Total	
	Impacts	Impacts	Impacts	Impacts	
Labor Income Impacts (millions of dollars)	9.72	0.92	8.02	18.66	
Output Impacts (millions of dollars)	5.54	2.53	24.16	32.23	
Employment Impacts (full-time and part-time jobs)	340.59	20.61	209.33	570.53	
Impacts of Aquaculture Cod Offshore Shipments	s – All Sec	ctors			
	Direct	Indirect	Induced	Total	
	Impacts	Impacts	Impacts	Impacts	
Labor Income Impacts (millions of dollars)	15.18	4.81	13.72	33.70	
Output Impacts (millions of dollars)	18.41	16.54	41.30	76.25	
Employment Impacts (full-time and part-time jobs)	531.36	123.51	358.68	1,013.54	

Table 7.10. Basic production and cost requirements, Atlantic salmon.

Parameter	Description	Unit	Baseline Value	High-end
				Value
ν	cage volume per cohort	m ³	5,000	5,000
acq	cage purchase cost	\$/m ³	15.00	25
inst	cage mooring and installation cost ^a	\$/m ³	3.00	3.00
cm	cage operating and maintenance cost ^b	\$/m ³ /year	1.00	6
stock	number of fingerlings stocked per cohort	1,000 fish	45	45
sg	stocking weight	gram/fish	150	150
φ	ratio of water weight to fingerling weight during transport to farm		5	5
sp	fingerling cost	\$/fish	1.50	1.75
fp	feed cost	\$/kg	0.73	0.9
bfix	vessel fixed cost	\$/year	100,000	150,000
bvar	vessel variable and crew cost c	\$day	3,000	3,000
ld	vessel payload	MT	30	30
trip	round trips per day		3	3
sh	on shore cost d	\$/year	150,000	250,000
ins	insurance cost ^e	\$/year	50,000	300,000
fmv	feed management variable cost	\$/cohort/month	0	33.32
scf	solid control BMP plan fixed cost	\$/farm	0	1615.20
scv	solid control BMP plan variable cost	\$/month	0	21.15
dcf	drug and chemical control BMP plan fixed cost	\$/farm	0	1615.20
dcv	drug and chemical control BMP plan variable cost	\$/month	0	21.15
aff	active feed monitoring fixed cost	\$/farm	0	10,000
afv	active feed monitoring fixed cost	\$/cohort/month	0	33.32
δ	annual discount rate		0.07	0.07

a. Including feeder and other equipments

b. Including fuel, utilities, diving, repair, etc.

c. Including 4 crews (average \$25/hour)

d. Including salaries for 1 manager and 2 office staff

e. Insurance covers fish and other capital

Table 7.11. Estimated net present value, investment, harvest, and cost, Atlantic salmon.

Output Variable	Description	Unit	Baseline Value	High-end Value
NPV	net present value	\$ million	29.486	14.289
I	investment	\$ million	2.010	3.139
x(T)	average fish harvest	metric ton/month	169	169
n(T)	average number of fish harvested	fish/month	37,446	37,446
w(T)	average harvest fish size	kg	4.52	4.52
$12 \cdot E[fq(t)]$	average feed quantity	metric ton/year	2,619	2,619
Project Cost	total cost	\$ million	31.315	46.512
Cost Share	cage installation	%	6.4	6.7
	cage maintenance	%	3.2	13.2
	boat and crew	%	6.0	5.0
	fingerlings	%	24.0	18.8
	feed	%	54.5	45.3
	onshore and other	%	5.9	11.0
	total	%	100	100

Although the basic technology requires cages, actual production technology differs slightly for winter flounder than for cod and salmon. Stocking and harvesting are restricted to two-month periods per year; stocking occurs between March and April and harvesting occurs between November and December. Input and cost requirements are summarized in Table 7.13. The total cost of the operation over the 15-year period varies between \$7.31 million (baseline product) and \$8.8 million (high-end product). (See Table 7.14.) The estimated net present value for the baseline product is \$1.23 million over the 15-year period. The net present value for the high-end product is negative and equals -\$0.3 million. Additional analysis indicates that the operation is no longer economically feasible if the price received falls below \$1.59 per pound.

The farm operation is projected to produce 3.3 million pounds of flounder per year, while receiving approximately \$15.2 million is gross sales. The economic activity which might be generated from a flounder aquaculture operation is therefore quite significant. Total sales or output over all sectors is projected to be \$81.8 million; total income is projected to be \$37.9 million; and total employment is project to equal 1154.7 full- and part-time jobs (Table 7.15). The primary producing sector generates the highest level of sales or outputs, but the restaurant sector generates the highest levels of both income and employment.

Table 7.12. Economic contributions of salmon operation, \$8.1 million in annual sales.

Impacts of Aquaculture Salmon Shipments – Producers				
	Direct		Induced Impacts	
Labor Income Impacts (millions of dollars)	3.71			8.18
` ` ` ` ` ` ` ` ` ` ` ` ` ` ` ` ` ` ` `				
Output Impacts (millions of dollars)	4.71			
Employment Impacts (full-time and part-time jobs)			86.54	188.81
Impacts of Aquaculture Salmon Shipments – Wh			T	
			Induced Impacts	
Labor Income Impacts (millions of dollars)	0.29	0.05	0.23	0.58
Output Impacts (millions of dollars)	0.33	0.16	0.70	1.19
Employment Impacts (full-time and part-time jobs)	5.49	1.16	6.10	12.75
Impacts of Aquaculture Salmon Shipments – Gro	ocers			
impacts of requirement Summon Simplificities of		Indirect	Induced	Total
			Impacts	
Labor Income Impacts (millions of dollars)	0.48	•	•	•
Output Impacts (millions of dollars)	0.30			
Employment Impacts (full-time and part-time jobs)	16.99			
Impacts of Aquaculture Salmon Shipments – Res				
	Direct	Indirect	Induced	Total
			Impacts	
Labor Income Impacts (millions of dollars)	5.18			9.95
Output Impacts (millions of dollars)	2.95	1.35	12.88	17.18
Employment Impacts (full-time and part-time jobs)	181.58	10.99	111.60	304.16
Impacts of Aquaculture Salmon Shipments – All	Sectors			
	Direct		Induced	
		•	Impacts	•
Labor Income Impacts (millions of dollars)	9.67			
Output Impacts (millions of dollars)	8.29			
Employment Impacts (full-time and part-time jobs)	276.16	43.20	214.32	533.68

Table 7.13. Basic production and cost requirements, winter flounder.

Parameter	Description	Unit	Baseline	High-end Value	
		_	Value		
V	cage volume per cohort	m^3	5,000	5,000	
acq	cage purchase cost	\$/m ³	15.00	25	
inst	cage mooring and installation cost ^a	\$/m ³	3.00	3.00	
ст	cage operating and maintenance cost b	\$/m ³ /year	1.00	6	
stock	number of fingerlings stocked per cohort	1,000 fish	130	130	
Sg	stocking weight	gram/fish	500	500	
φ	ratio of water weight to fingerling weight during transport to farm		5	5	
Sp	fingerling cost	\$/fish	2.00	2.00	
Sp	feed cost	\$/kg	0.65	0.73	
bfix	vessel fixed cost	\$/year	20,000	30,000	
bvar	vessel variable and crew cost c	\$day	3,000	3,000	
ld	vessel payload	MT	30	30	
trip	round trips per day		3	3	
sh	on shore cost d	\$/year	40,000	70,000	
ins	insurance cost ^e	\$/year	10,000	60,000	
fmv	feed management variable cost	\$/cohort/month	0	33.32	
scf	solid control BMP plan fixed cost	\$/farm	0	1615.20	
SCV	solid control BMP plan variable cost	\$/month	0	21.15	
dcf	drug and chemical control BMP plan fixed cost	\$/farm	0	1615.20	
dcv	drug and chemical control BMP plan variable cost	\$/month	0	21.15	
aff	active feed monitoring fixed cost	\$/farm	0	10,000	
afv	active feed monitoring fixed cost	\$/cohort/month	0	33.32	
δ	annual discount rate		0.07	0.07	

- a. Including feeder and other equipments
- b. Including fuel, utilities, diving, repair, etc.
- c. Including 4 crews (average \$25/hour)
- d. Including salaries for 1 manager and 2 office staff
- e. Insurance covers fish and other capital

Table 7.14. Estimated net present value, investment, harvest, and cost, winter flounder.

Output	Description	Unit	Baseline	High-end
Variable			Value	Value
NPV	net present value	\$ million	1.234	-0.303
I	investment	\$ million	0.175	0.286
x(T)	average fish harvest*	metric ton/month	125	125
n(T)	average number of fish harvested*	fish/month	121,791	121,791
w(T)	average harvest fish size	kg	1.03	1.03
$12 \cdot E[fq(t)]$	average feed quantity	metric ton/year	175	175
Project Cost	total cost	\$ million	7.307	8.844
Cost Share	cage installation	%	2.4	3.2
	cage maintenance	%	1.2	6.3
	boat and crew	%	9.0	8.5
	fingerlings	%	66.7	55.1
	feed	%	14.3	13.3
	onshore and other	%	6.3	13.6
N. d. FD	total	%	100	100

Note: * There are only two cohorts in a year (harvested in Nov. and Dec., respectively). Average annual harvest is the monthly figure times two.

Summary and Conclusions

Despite apparent evidence that offshore aquaculture is not only economically feasible but also capable of generating substantial contributions to the U.S. economy, there remain many obstacles which may hinder its development and adoption. In this study, it was demonstrated that production of five species popular with U.S. consumers is economically feasible, provided certain conditions prevailed. Foremost among these conditions is that prices received will hold at certain levels. Given the increasing level of imports, it is quite possible that prices received for the primary products will decrease. Also, if resource conditions do improve in the future, the landings of wild-caught cod and winter flounder would likely expand. The sea scallop resource is already at a high level of biomass. In addition, all of the species can be produced near-shore as opposed to offshore, and there are likely to be cost savings for inshore or near-shore operations.

There remain many other concerns which may limit the development of offshore aquaculture outlined in other chapters in this report. There are potential uncertainties about obtaining loans, which will be necessary for satisfying up front investment costs. In all instances, these investment costs are quite high and will likely deter individuals or firms from investing in offshore aquaculture. There is considerable uncertainty about what constitutes best management practices (BMPs) for various operations. Present analysis does, however, support the development of offshore aquaculture in waters within 25 nautical miles of shore. Finally, it

is concluded that operations farther offshore will require larger projects, or farms, and higher levels of investment.

Table 7.15. Economic contributions of flounder operation, \$8.1 million in annual sales.

Table 7.13. Economic contributions of nounder operation, 40.1 million in aimual saics.								
Impacts of Aquaculture Winter Flounder Offshore Shipments – Producers								
	Direct	Indirect	Induced	Total				
	Impacts	Impacts	Impacts	Impacts				
Labor Income Impacts (millions of dollars)	5.34	3.50	5.20	14.03				
Output Impacts (millions of dollars)	13.20	11.37	15.60	40.17				
Employment Impacts (full-time and part-time jobs)	219.29	80.04	136.10	435.44				
Impacts of Aquaculture Winter Flounder Offshore Shi	pments –	Wholesa	lers					
	Direct	Indirect	Induced	Total				
	Impacts	Impacts	Impacts	Impacts				
Labor Income Impacts (millions of dollars)	0.61	0.11	0.49	1.21				
Output Impacts (millions of dollars)	0.69	0.33	1.47	2.48				
Employment Impacts (full-time and part-time jobs)	11.46	2.42	12.73	26.61				
Impacts of Aquaculture Winter Flounder Offshore Shipments – Grocers								
	Direct	Indirect	Induced	Total				
	Impacts	Impacts	Impacts	Impacts				
Labor Income Impacts (millions of dollars)	1.00	0.09	0.81	1.89				
Output Impacts (millions of dollars)	0.62	0.24	2.42	3.29				
Employment Impacts (full-time and part-time jobs)	35.41	1.86	21.02	58.30				
Impacts of Aquaculture Winter Flounder Offshore Shipments – Restaurants								
	Direct	Indirect	Induced	Total				
	Impacts	Impacts	Impacts	Impacts				
Labor Income Impacts (millions of dollars)	10.81	1.03	8.92	20.75				
Output Impacts (millions of dollars)	6.16	2.81	26.86	35.83				
Employment Impacts (full-time and part-time jobs)	378.70	22.92	232.75	634.37				
Impacts of Aquaculture Winter Flounder Offshore Shipments – All Sectors								
	Direct	Indirect	Induced	Total				
	Impacts	Impacts	Impacts	Impacts				
Labor Income Impacts (millions of dollars)	17.76	4.72	15.40	37.89				
Output Impacts (millions of dollars)	20.67	14.76	46.35	81.78				
Employment Impacts (full-time and part-time jobs)	644.87	107.24	402.61	1154.72				

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